Variability in Size or Age at Sexual Maturity of White Hake, Pollock, Longfin Hake, and Silver Hake in the Canadian Maritimes Area of the Northwest Atlantic Ocean

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VARIABILITY IN SIZE OR AGE AT SEXUAL MATURITY OF WHITE HAKE, POLLOCK, LONGFIN HAKE, AND SILVER HAKE IN THE CANADIAN MARITIMES AREA OF THE NORTHWEST ATLANTIC OCEAN

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ABSTRACT

Beacham, Terry D. 1983. Variability in size or age at sexual maturity of white hake, pollock, longfin hake, and silver hake in the Canadian Maritimes area of the Northwest Atlantic Ocean. Can. Tech. Rep. Fish. Aquat. Sci. 1157: iv + 43 p.

The length or age at which 50% of the individuals were mature were calculated for white hake (Urophycis tenuis), pollock (Pollachius virens), longfin hake (Phycis chesteri) and silver hake (Merluccius bilinearis) in the Northwest Atlantic. Median length at maturity for white hake generally declined through time and males matured at smaller lengths than did females. During 1959-1979, median length at maturity for male U. tenuis ranged from 46 to 39 cm, while that for females ranged from 58 to 45 cm, respectively. Median length and age at maturity for pollock generally declined through time and males matured at smaller sizes and younger ages than did females. During 1970-1974, median length at maturity for males ranged from 47 to 50 cm, while median age at maturity ranged from 3.3-3.8 yr, respectively. Median length (and age) of females ranged from 49 cm (3.4 yr) to 51 cm (4.0 yr), respectively. Median length at maturity for longfin hake was 30 cm for males and 32 cm for females. For silver hake, median length at maturity for males ranged from 26.8 cm in Subdiv. 4Vs to 23.6 cm in Div. 4X, while median age at maturity ranged from 2.0 to 1.4 yr, respectively. Median length (and age) of females ranged from 27.8 cm (2.0 yr) to 25.9 cm (1.6 yr), respectively. Pollock and silver hake in warmer waters matured at younger ages than did those in colder waters.

Keywords: longfin hake, maturity, Northwest Atlantic, pollock, population dynamics, silver hake, white hake.

RÉSUMÉ

Beacham, Terry D. 1983. Variability in size or age at sexual maturity of white hake, pollock, longfin hake, and silver hake in the Canadian Maritimes area of the Northwest Atlantic Ocean. Can. Tech. Rep. Fish. Aquat. Sci. 1157: iv + 43 p.

Nous avons calculé la longueur et l'âge auxquels sont matures, dans l'Atlantique nord-ouest, 50 % des individus des espèces suivantes: la merluche blanche (Urophysis tenuis), la goberge (Pollachius virens), la merluche à longues nageoires (Physis chesteri) et le merlu argent (Merluccius bilinearis). La longueur médiane de la merluche blanche mature a, de façon générale, diminué pendant la période étudiée, tandis que les mâles ont atteint la maturité à une longueur inférieure à celle des femelles. De 1959 à 1979, la longueur médiane des U. tenuis mâles matures est passée de 46 à 39 cm; celle des femelles a chuté de 58 à 45 cm. Chez la goberge mature, la longueur et l'âge médians ont généralement baissé pendant la période étudiée et les mâles ont atteint la maturité à un âge et une longueur inférieurs à ceux des femelles. De 1970 à 1974, la longueur et l'âge médians à maturité ont varié de 47 à 50 cm et de 3,3 à 3,8 ans chez les mâles, et de 49 à 51 cm et de 3,4 à 4,0 ans, chez les femelles. Pour la merluche à longues nageoires mature, la longueur médiane des femelles et des mâles à maturité s'est élevée à 32 cm et à 30 cm respectivement. La longueur médiane du merlu argenté mâle mature a atteint 26,8 dans la division 4Vs et 23,6 cm dans la division 4X, tandis que l'âge médian à maturité a varié de 2,0 à 1,4 ans. La longueur et l'âge médians des femelles sont passés de 27,8 cm à 25,9 cm et de 2,0 ans à 1,6 an respectivement. La goberge et le merlu argenté peuplant les eaux plus chaudes ont atteint la maturité plus tôt que leurs congénères des eaux froides.

Mots-clés: merluche à longues nageoires, Atlantique nord-ouest, goberge, dynamique des populations, merlu argenté, merluche blanche

INTRODUCTION

White hake (Urophycis tenuis) is distributed in the western Atlantic Ocean from Newfoundland to Cape Hatteras (Leim and Scott 1966), and is exploited by commercial fisheries mainly in Northwest Atlantic Fisheries Organization Subareas 3 and 4 (Fig. 1), with the majority of the Subarea 4 catch taken in the southern Gulf of St. Lawrence (Div. 4T) (Beacham and Nepszy 1980). Kohler (1971) concluded that white hake in Div. 4T is a unit stock, but stock delineation of white hake on the Scotian Shelf (Divs. 4VWX) is uncertain. Leim and Scott (1966) have outlined aspects of the general biology of white hake.

Canadian groundfish surveys have indicated that pollock (Pollachius virens) is most abundant off southwestern Nova Scotia in Northwest Atlantic Fisheries Organization Div. 4X (Fig. 1), and is less abundant on the northern Scotian Shelf (Div. 4V) and off Cape Breton (Scott 1976). Little is known about pollock migrations on the Scotian Shelf, although Clark et al. (1977) present data for seasonal distributions of nominal catches which suggest that there is a southward spawning migration in the fall and winter of pollock from Div. 4X into the Gulf of Maine (Div. 5Y). The Canadian fishery for pollock is conducted mainly in Div. 4X (Cleary 1980).

Canadian groundfish surveys have indicated that silver hake (Merluccius bilinearis) is abundant off southwestern Nova Scotia, but are relatively scarce in the Bay of Fundy and north of Banquereau Bank (Subdiv. 4Vn) (Scott 1976; Hunt 1978). Silver hake were most abundant in depths greater than 100 fathoms. Little is known about seasonal migrations of silver hake on the Scotian Shelf. The Soviet Union has been the main exploiter of silver hake on the Scotian Shelf, with a reported catch of 300,000 metric tonnes in 1973, with the fishery conducted by small-mesh otter trawlers. Silver hake spawn between June and August (Leim and Scott 1966; Sarnits and Sauskan 1967), and thus summer groundfish surveys would be well timed in order to assess the reproductive condition of individual fish.

Growth rates of individuals and reproductive potential of a population are important parameters in an investigation of population dynamics. Changes in size or age at maturity may have a great impact on stock population dynamics. The present paper describes variability in median size or age at sexual maturity of white hake, pollock, longfin hake, and silver hake from data collected during Canadian groundfish surveys in the Northwest Atlantic.

MATERIALS AND METHODS

The data analyzed in the present paper were derived from Canadian groundfish surveys of the M/V HARENGUS, E.E/PRINCE, and A.T. CAMERON during the period 1959-1979. Groundfish surveys in the southern Gulf of St. Lawrence .

were conducted primarily in September whereas surveys in the other areas were conducted primarily in July. Maturity ogives based on length were calculated if possible for four periods: 1959-1964, 1965-1969, 1970-1974, and 1975-1979. All surveys conducted in each interval were included in the analysis. Groundfish surveys on the M/V HARENGUS were conducted with a ∂35 Yankee otter trawl, those on the E.E. PRINCE with a ∂36 Yankee otter trawl, and those on the A.T. CAMERON before 1970 with a ∂41 A Western otter trawl, and subsequently with a ∂36 Yankee otter trawl. Further details on the sampling gear used were outlined by Jean (1964). During the surveys, total length of white hake and longfin hake and fork length of pollock and silver hake were recorded to the nearest cm on fresh dead individuals. The stages of maturity outlined for cod (Gadus morhua) by Powles (1958) were used in assessing maturity of the species. There has been uncertainty over ageing silver hake by otoliths (Hunt 1978), but silver hake in this study were aged by otoliths according to the method of Hunt (1978).

The transition from the immature to the mature condition in fish usually occurs over a range of length in the form of a sigmoid curve. From the percentage of mature individuals (gonads in ripening, ripe, spawning, spent, or recovering condition) in either 2-cm or 4-cm length intervals in the period under consideration, the median (50%) length at sexual maturity was calculated by probit analysis following the technique of Leslie et al. (1945). Median age at sexual maturity was calculated in a similar manner by grouping the data in 1-year intervals.

RESULTS

Urophycis tenuis

Div. 4T

Median length at sexual maturity has declined for white hake in Div. 4T during 1959-1964 to 1975-1979 (Fig. 2). Median length at maturity for males declined from 47 cm during 1965-1969 to 40 cm during 1975-1979 ($P<0.05$), while that for females declined from 52 cm to 47 cm, respectively ($P<0.05$) (Table 1). There was a tendency for an increasing proportion of smaller white hake to become mature through time. No males less than 40 cm in length were mature during 1959-1964, but over 40% were mature during 1975-1979. This same trend was also evident for females.

Subdiv. 4Vn

White hake in Subdiv. 4Vn had similar trends in size at maturity to those in Div. 4T. For males, median length at sexual maturity declined 9 cm from 46 cm in 1959-1964 to 37 cm in 1975-1979, ($P<0.05$), while that for females declined 14 cm from 59 to 45 cm, respectively ($P<0.05$) (Fig. 3). As in white hake in Div. 4T, there was an increasing proportion of smaller mature white hake through time, so that there was a decline in the length at which 0% of the fish were mature. However, there was no decline in the length at which

100% of the fish were mature, so that the transition from the immature to the mature state occurred over a larger length interval in the 1970s than in the 1960s.

Subdiv. 4Vs

Median length at sexual maturity has declined in males from 43 cm during 1959-1964 to 39 cm during 1975-1979 ($P<0.05$), while that of females has declined from 54 to 46 cm, respectively ($P<0.05$) (Fig. 4). More smaller white hake were mature in the 1970s than during 1959-1964, so that there was a decline in median length at sexual maturity.

Pollachius virens

Subdiv. 4Vs

Pollock have been infrequently sampled in Canadian groundfish surveys in Subdiv. 4Vs, and consequently data on variability in median size and age at sexual maturity were limited. Changes in percent mature by age (Table 2) indicate that in the 1970s, median age at maturity for males was 3.4 yr and 3.8 yr for females, and that males matured at younger ages than did females.

Div. 4W

Maturity ogives based on length have been variable through time owing to small sample sizes (Fig. 5). During 1959-1974, median length at maturity for males was about 49 cm, but from 1975-1979 declined to 33 cm. However, the data were variable in latter period, and the calculated 50% value had wide confidence limits, so that the decline was not significant ($P>0.05$). From 1959-1974, median length at sexual maturity for females ranged between 50 and 60 cm, but declined to 31 cm during 1975-1979, although not significantly ($P>0.05$). Males generally matured at smaller lengths than did females. Larger, immature pollock became relatively less abundant in the population with time. During 1975-1979, 100% of females 55 cm in fork length were mature, but from 20-60% of females 55 cm in length were mature in the 1960s (Fig. 5). During 1975-1979, over 60% of males 40 cm in length were mature, but virtually no males 40 cm in length were mature in the 1960s.

Changes in percentage mature by age indicated a substantial increase through time in ages 3 and 4 (Table 3), and thus a decline in median age at maturity. Although no pollock aged 4 yr were mature during 1959-1964, about 85% were mature during 1975-1979. During 1975-1979, virtually all age-5+ pollock were mature. Males tended to mature at younger ages than did females.

Div. 4X

Median length at maturity declined for male pollock in Div. 4X from 52 cm during 1959-1964 to 46 cm during 1975-1979, a significant decline ($P<0.05$) (Fig. 6). Median length at maturity for females declined from 55 cm in 1959-64 to about 50 cm from 1965-1979 ($P<0.05$). Virtually all females 60 cm in length were mature during 1975-1979, but about only 70% were mature during 1959-1964 (Fig. 7). About 45% of males 45 cm in length were mature

during 1975-1979, but less than 10% of males 45 cm in length were mature in the 1960s (Fig. 6). Larger, immature pollock have become less abundant in the population through time.

As in pollock in Div. 4W, there has been a substantial increase in percentage mature through time in age 3 and 4 (Table 4). About 70-80% of age-4 pollock were mature during 1975-79. The percentage of mature age-3 pollock during 1975-1979 was 32% larger for males and 69% larger for females compared with pollock during 1970-1974. During 1975-1979, median ages at maturity were about 3.2 yr for both males and females.

Phycis chesteri

Longfin hake have been caught in sufficient numbers during Canadian groundfish surveys only in Subdiv. 4Vn during 1975-1979 in order for median lengths at maturity to be calculated. Median lengths at maturity (and 95% confidence limits) were 30.2 cm (22.8-40.0) for males and 32.3 cm (29.8-35.0) for females (Fig. 7).

Merluccius bilinearis

Subdiv. 4Vs

Silver hake have been caught relatively infrequently in Canadian groundfish surveys in Subdiv. 4Vs, and there were not sufficient data to investigate annual variability in median size and age at sexual maturity. A maturity ogive based on length with data pooled during 1975-1979 indicated that median length at maturity for males was 27 cm and for females 28 cm (Fig. 8). Median ages at maturity were about 2.0 yr for both sexes, as the percentage mature by age was similar for both sexes (Table 5). Virtually all silver hake greater than 32 cm in length were mature during 1975-1979, as were most 3-yr-olds.

Div. 4W

Silver hake were more abundant in the catches of the groundfish surveys in Div. 4W than in Subdiv. 4Vs (Scott 1976), so it was possible to examine annual variability in median size and age at sexual maturity. Median lengths at maturity were larger in 1964 than in the 1970s (Fig. 9). There was some tendency for median lengths at maturity to increase during 1970-1977, and decline during 1977-1979. Median ages at maturity for males were relatively constant between 1972 and 1979 at about 1.5 yr, whereas those for females during 1977-1979 were about 0.3-0.6 yr greater than during 1973-1976 (Fig. 10). Males matured at smaller lengths and younger ages than did females.

Maturity ogives based on length and age were calculated for the four periods analyzed in this study. For males, median length at maturity was about 29 cm during 1959-1964, but declined to 24 cm during 1965-1979 ($P<0.01$) (Fig. 11). Median lengths for females ranged between 26 and 27 cm for the four periods analyzed, and there were no significant differences among periods. About 30% of males of 30 cm in length were immature during 1959-1964, but virtually 100% were mature during 1965-1979.

The relative stability of the maturity ogive based on length was apparent in percentage mature at age in the 1970s (Table 6). Median ages at maturity were about 1.5 yr for males and 1.8 yr for females. Virtually all males were mature by age 2 and all females by age 3.

Div. 4X

The analysis of variability in median length at sexual maturity of silver hake sampled from Div. 4X indicated that the values could vary by 10-15% per year, especially in females (Fig. 12). For females, median ages at maturity were greater during 1977-1979 than during 1972-1976 ($P<0.05$) (Fig. 13). Males matured at smaller sizes and younger ages than did females. Median ages at maturity for males were relatively constant at about 1.4 yr, whereas those for females ranged between 1.5 and 2.1 yr.

Similar to silver hake in Div. 4W, median lengths at maturity for males declined from 27 cm from 1959-1964 to 24 cm in the 1970s ($P<0.05$) (Fig. 14). Median lengths for females declined from 31 cm in 1959-1964 to about 26 cm in the 1970s ($P<0.05$). About 20% of males 30 cm in length and 50% of females 30 cm in length were immature during 1959-1964, but virtually all 30-cm silver hake were mature in the 1970s.

The percentage mature by age was constant in the two periods examined (Table 7). Median ages at maturity were about 1.4 yr for males and 1.6 yr for females. Over 90% of males were mature by age 2 and virtually all females were mature by age 3.

COMPARISONS AMONG AREAS

Several trends were apparent when all areas were considered in the multi-year grouping of the groundfish surveys. Median lengths at sexual maturity generally declined through time for white hake and pollock. Males tended to mature at smaller lengths than did females for all species investigated. During 1970-1974, median length at maturity for male white hake in Subarea 4 was about 40 cm, while that for females was about 50 cm (Table 1). There was also a trend towards younger median ages at sexual maturity for pollock and silver hake in Divs. 4W and 4X. Males matured at younger ages than did females. Bottom water temperatures derived from all September groundfish surveys indicated that Div. 4T had the lowest water temperatures during 1970-1974 (2.2°C in September) and all July surveys indicated that Div. 4X had the highest (6.9°C in July). Because growth rates of white hake may be correlated with water temperature (Beacham and Nepszy 1980), then white hake in the more southerly areas probably mature at younger ages than do hake in more northerly areas. White hake have not been aged in samples from the groundfish surveys, so it was not possible to examine this aspect directly. However, by using the mean lengths-at-age derived from samples from the commercial fishery as reported by Beacham and Nepszy (1980), one could suggest that in Divs 4T and 4V, 50% of females were mature at about 3.5 y of age during 1975-1979. When data were pooled during 1970-1979, pollock in Divs. 4Vs and 4W had older median ages at maturity than those in Div. 4X. Growth rates of pollock on the Scotian Shelf are correlated with water temperature (Beacham 1982), so pollock that have slower growth rates tend to mature at older ages than do faster-growing pollock. Similar results were found for silver hake.

DISCUSSION

Confusion has existed as to the species of Urophycis caught in Subarea 4 in the southern Gulf of St. Lawrence and on the Scotian Shelf (Markle et al. 1980), but Musick (1967), on the basis of morphological criteria, suggested that all hake caught in Div. 4T and Subdivs. 4Vn and 4Vs were white hake, U. tenuis. Red hake (U. chuss) is smaller than white hake (U. tenuis) and matures at 28-30 cm (Musick 1967). Red hake was considered not to have been sampled in the present study. Markle et al (1982) has outlined differences between white hake and red hake.

The decline in median size at sexual maturity for white hake, pollock, and to some extent silver hake may have occurred for two reasons. To the extent that size at maturity has a genetic component (Alm 1959), then there has been selection for fish that mature at smaller sizes and younger ages. Commercial exploitation would remove genotypes that mature at larger sizes and older ages, and this mechanism could account for the decline in median length at maturity and in some cases the decreasing abundance of larger, older, immature fish with time. Another explanation could be that if size at maturity is dependent upon growth rate, then an increase in growth rates could account for a decline in age at maturity. In a study of sexual maturity of haddock (Melanogrammus aeglefinus) on the Grand Bank of Newfoundland (Subarea 3), Templeman et al. (1978) attributed a decline in length at 50% maturity from 1951-1960 to declining growth rate associated with increased abundance and an increase in length at 50% maturity during 1961-1966 to increasing growth rate associated with decreased abundance. Information on stock abundance of white hake and pollock is not available during 1959-1979, but declines in stock biomass of other gadoids in Subarea 4 declined during a period of heavy exploitation in the 1960s and early 1970s (Halliday 1971, 1972; O'Boyle MS 1980). If median length at maturity is directly related to growth rate as suggested by Templeman et al. (1978), then median length at maturity in white hake and pollock should have increased with time as stock biomass presumably declined. These results suggest that in these species, median length at maturity is not simply related with growth rate. A decline in median length at maturity may be a density-dependent response attributable to a decline in stock biomass, but further data are necessary to distinguish between selection and environmental effects.

Variability in median length at sexual maturity for white hake and pollock has not been extensively investigated. A generalized account was given by Leim and Scott (1966). Beacham and Nepszy (1980) illustrated annual variability for white hake in Div. 4T between 1970-1978, and the present study illustrated regional trends through time. Steele (1963) reported that for pollock caught during 1960-61 in Div. 4X, median lengths at maturity were 58 cm for males and 63 cm for females, and median ages were about 4.7 and 5.2 yr, respectively. These lengths and ages were larger than those recorded in the present study for Div. 4X pollock from 1959-1964 (Tables 4, 5), but this may be due to the different intervals grouped in the studies. Median ages at maturity for pollock in the present study were also younger than those recorded by Barents Sea pollock by Mironova (1961).

Reproductive biology of silver hake on the Scotian Shelf has been outlined in a general manner by Leim and Scott (1966). Variability in size and age at sexual maturity for silver hake on the Scotian Shelf was investigated by Doubleday and Halliday (1976). They found that between 1971 and 1974 for silver hake in Divs. 4VWX combined, almost all males greater than 25 cm were mature, with the median length about 24 cm, and almost all females greater than 30 cm were mature, with the median length about 27 cm. They concluded that all age-1 males were immature and all age-2 males mature, but that, on the average, 75% of age-2 females were mature. The results of the present study agree with those of Doubleday and Halliday (1976). The present study extends the analysis, and indicates no marked change in size and age at maturity during 1975-1979.

The present study indicated that pollock and silver hake caught in warmer waters matured at younger ages than in colder waters. This general trend was noted by Gunter (1950), who suggested that fish inhabiting regions of higher water temperature grew faster initially, attained sexual maturity earlier, and were of smaller final size than the same species in colder water. Alm (1959) noted that fish with a higher initial growth rate attained sexual maturity earlier than did slower-growing fish of the same species, and the results of the present study support that view. Future research should investigate variability in median size and age at sexual maturity in relation to stock population dynamics.

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Table 1. Median length (cm) at sexual maturity, for white hake and pollock in the Northwest Atlantic as calculated from Canadian groundfish surveys during 1959-1979. Values in parentheses are 95% confidence limits.

	Males			
Division	1959-1964	1965-1969	1970-1974	1975-1979
		Urophycis tenuis		
4T	-	47.2 (45.5-49.1)	41.5 (40.4-42.6)	40.4 (39.8-41.0)
4Vn	46.1 (42.4-50.1)	-	40.3 (38.7-42.0)	36.8 (35.1-38.6)
4Vs	43.0 (41.2-44.8)	-	39.3 (36.9-41.8)	38.6 (37.6-39.7)
		Pollachius virens		
4W	49.5 (46.6-52.6)	48.3 (43.6-53.4)	50.5 (46.9-54.4)	33.3 (22.7-48.1)
4X	52.1 (49.1-55.2)	49.1 (44.3-54.0)	47.3 (45.7-49.0)	45.9 (43.6-48.2)
		Merluccius bilinearis		
4Vs	-	-	-	26.8 (25.4-28.3)
4W	27.8 (27.2-28.5)	23.8 (23.5-24.1)	23.9 (23.7-24.2)	24.1 (23.8-24.4)
4X	26.8 (25.0-28.6)	25.1 (24.6-25.5)	23.6 (23.3-24.0)	23.6 (23.2-24.0)

Table 1 (cont'd)

Division	Females			
	1959-64	1965-1969	1970-1974	1975-1979
		Urophycis tenuis		
4T	54.8 (53.0-56.7)	52.4 (50.6-54.2)	49.7 (47.6-51.9)	47.1 (46.2-48.0)
4Vn	58.5 (56.5-60.5)	-	49.3 (45.0-54.0)	45.0 (43.2-46.9)
4Vs	54.3 (50.2-58.7)	-	50.3 (43.1-58.8)	45.4 (44.2-46.6)
		Pollachius virens		
4W	52.8 (50.2-55.6)	59.5 (54.4-65.1)	50.6 (47.6-53.8)	31.0 (15.3-66.2)
4X	54.6 (51.8-57.3)	49.8 (44.6-55.4)	48.7 (46.6-50.8)	50.1 (48.4-51.9)
		Merluccius bilinearis		
4Vs	-	-	-	27.8 (26.7-29.0)
4W	27.1 (26.5-27.7)	26.1 (25.8-26.4)	26.1 (25.8-26.3)	27.4 (27.1-27.7)
4X	31.1 (28.9-33.5)	27.5 (27.2-27.9)	25.6 (25.3-25.9)	25.9 (25.5-26.4)

Table 2. Percentages of sexually mature pollock by age and sex caught by Canadian research vessels in Subdiv. 4Vs, 1970-1979. Sample sizes are in parentheses for individual ages and 95% confidence limits for A_{50} (yr).

Age (yr)	Male	Female
2	0.0 (2)	0.0 (0)
3	50.0 (2)	0.0 (0)
4	66.7 (6)	57.1 (7)
5	100.0 (7)	80.0 (5)
6	100.0 (6)	100.0 (7)
A50	3.36(2.66-4.23)	3.78(2.55-5.60)

Table 3. Percentages of sexually mature pollock by sex and age caught by Canadian research vessels in Division 4W, 1959-1979. Sample sizes are in parentheses for individual ages and 95% confidence limits for A_{50} (yr).

Age (yr)	1959-1964	1970-1974	1975-1979
		Male	
2	- (0)	8.0 (25)	100.0 (2)
3	0.0 (4)	22.0 (50)	50.0 (12)
4	0.0 (3)	41.2 (17)	85.2 (27)
5	100.0 (5)	86.7 (15)	100.0 (16)
6	80.0 (5)	91.7 (12)	95.2 (21)
7	91.7 (12)	100.0 (4)	100.0 (5)
8	100.0 (16)	100.0 (6)	100.0 (7)
A_{50}	4.57(3.71-5.62)	3.84(3.48-4.24)	3.05(2.62-3.55)
		Female	
2	- (0)	5.6 (18)	0.0 (0)
3	0.0 (6)	23.1 (39)	75.0 (16)
4	0.0 (3)	37.5 (32)	83.3 (18)
5	80.0 (5)	75.0 (16)	100.0 (26)
6	83.3 (12)	92.9 (14)	100.0 (16)
7	88.9 (9)	100.0 (6)	100.0 (10)
8	92.3 (13)	100.0 (1)	100.0 (7)
9	100.0 (17)	100.0 (2)	100.0 (2)
A_{50}	4.68(3.70-5.92)	4.03(3.67-4.43)	2.48(1.75-3.50)

Table 4. Percentages of sexually mature pollock by sex and age caught by Canadian research vessels in Division 4X, 1959-1979. Sample sizes are in parentheses for individual ages and 95% confidence limits for A50 (yr).

Age (yr)	1959-1964	1970-1974	1975-1979
		Male	
1	- (0)	0.0 (3)	0.0 (2)
2	0.0 (1)	0.9 (115)	2.0 (50)
3	16.7 (3)	29.2 (65)	38.7 (31)
4	80.0 (6)	89.2 (65)	80.0 (70)
5	100.0 (5)	98.0 (50)	95.9 (98)
6	100.0 (6)	95.5 (22)	98.3 (59)
7	100.0 (2)	100.0 (18)	100.0 (34)
A50	4.51(4.05-5.01)	3.25(3.11-3.41)	3.25(3.05-3.46)
		Female	
1	- (0)	0.0 (0)	0.0 (2)
2	- (0)	0.0 (108)	5.9 (17)
3	0.0 (5)	26.8 (41)	45.2 (31)
4	0.0 (2)	82.7 (81)	72.2 (79)
5	33.3 (3)	96.9 (65)	94.6 (111)
6	83.3 (6)	100.0 (26)	97.6 (82)
7	100.0 (2)	95.0 (20)	100.0 (67)
8	100.0 (1)	100.0 (15)	100.0 (31)
A50	5.27(4.60-6.04)	3.39(3.22-3.55)	3.22(2.98-3.49)

Table 5. Percentages of sexually mature silver hake by age and sex caught in otter trawls of Canadian research vessels in Subdiv. 4Vs, 1975-79. Sample sizes are in parentheses after individual ages and 95% confidence limits after A_{50} (yr).

Age (yr)	Male	Female
1	0.0 (4)	0.0 (12)
2	54.6 (23)	55.6 (39)
3	85.7 (7)	100.0 (21)
4	100.0 (13)	100.0 (33)
A_{50}	1.95 (1.64-2.31)	1.95 (1.80-2.12)

Table 6. Percentages of sexually mature silver hake by age and sex caught in otter trawls of Canadian research vessels in Division 4W, 1971-1979. Sample sizes are in parentheses after individual ages and 95% confidence limits after A_{50} (yr).

Age (yr)	1971-1974	1975-1979
	Male	
1	2.0 (247)	5.2 (232)
2	95.3 (275)	92.6 (220)
3	100.0 (31)	100.0 (152)
4	100.0 (12)	97.8 (46)
5	100.0 (6)	100.0 (17)
A_{50}	1.47 (1.41-1.52)	1.44 (1.41-1.52)
	Female	
1	1.6 (258)	0.5 (239)
2	74.2 (392)	64.4 (335)
3	96.0 (148)	98.1 (253)
4	98.5 (65)	99.1 (135)
5	100.0 (45)	100.0 (87)
A_{50}	1.71 (1.65-1.77)	1.83 (1.76-1.90)

Table 7. Percentages of sexually mature silver hake by age and sex caught in otter trawls of Canadian research vessels in Division 4X, 1972-1979. Sample sizes are in parentheses after individual ages and 95% confidence limits after A_{50} (yr).

Age (yr)	1972-1974	1975-1979
	Male	
1	7.0 (100)	8.8 (320)
2	93.0 (142)	93.2 (258)
3	100.0 (13)	100.0 (46)
A_{50}	1.42 (1.33-1.50)	1.39 (1.33-1.45)
	Female	
1	2.9 (104)	3.3 (374)
2	80.5 (277)	81.4 (435)
3	100.0 (44)	96.1 (195)
4	100.0 (39)	98.6 (69)
5	100.0 (51)	100.0 (47)
A_{50}	1.61 (1.54-1.69)	1.61 (1.55-1.66)

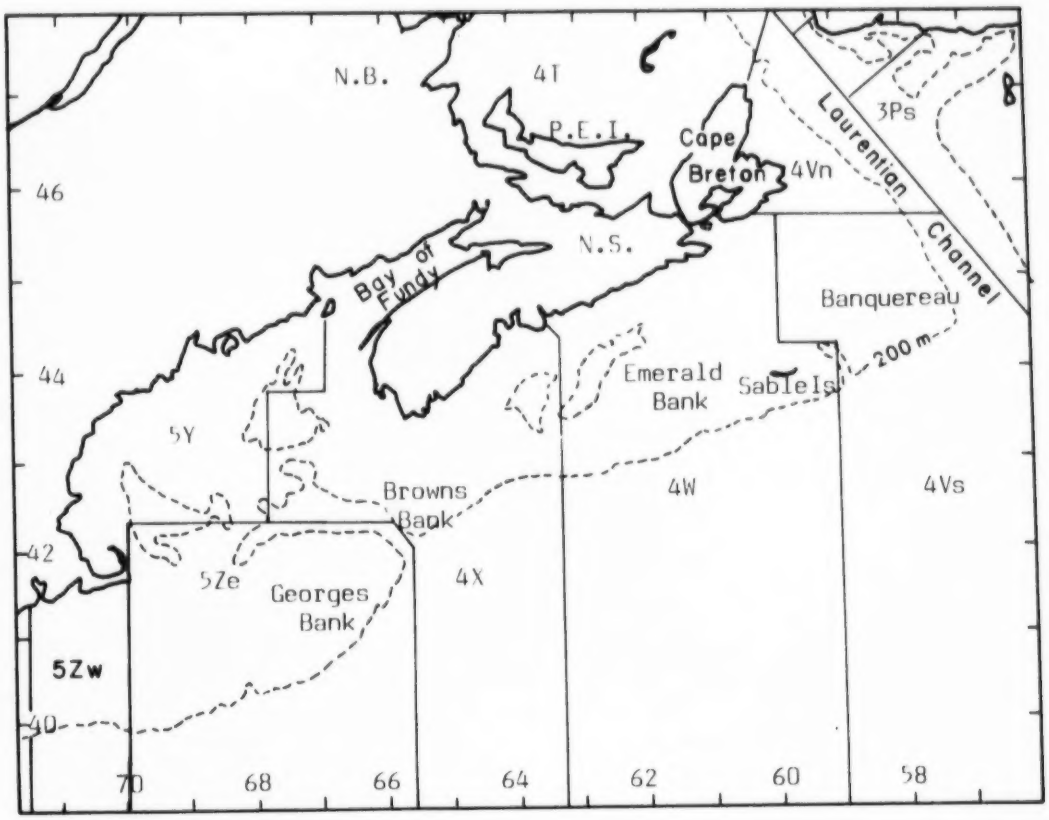

Fig. 1. Northwest Atlantic Fisheries Organization Divisions in Subarea 4.

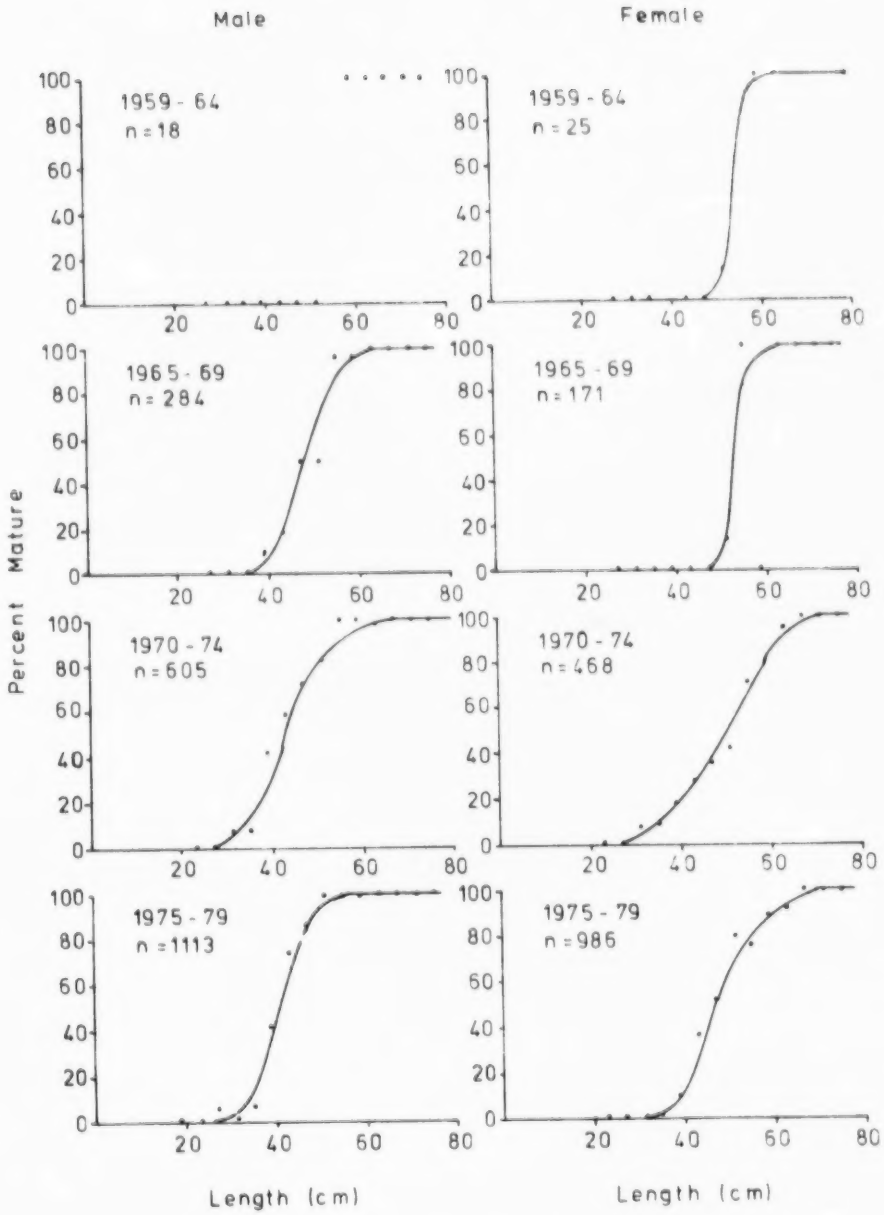

Fig. 2. Maturity ogives for white hake sampled during Canadian groundfish surveys in Div. 4T, 1959-1979.

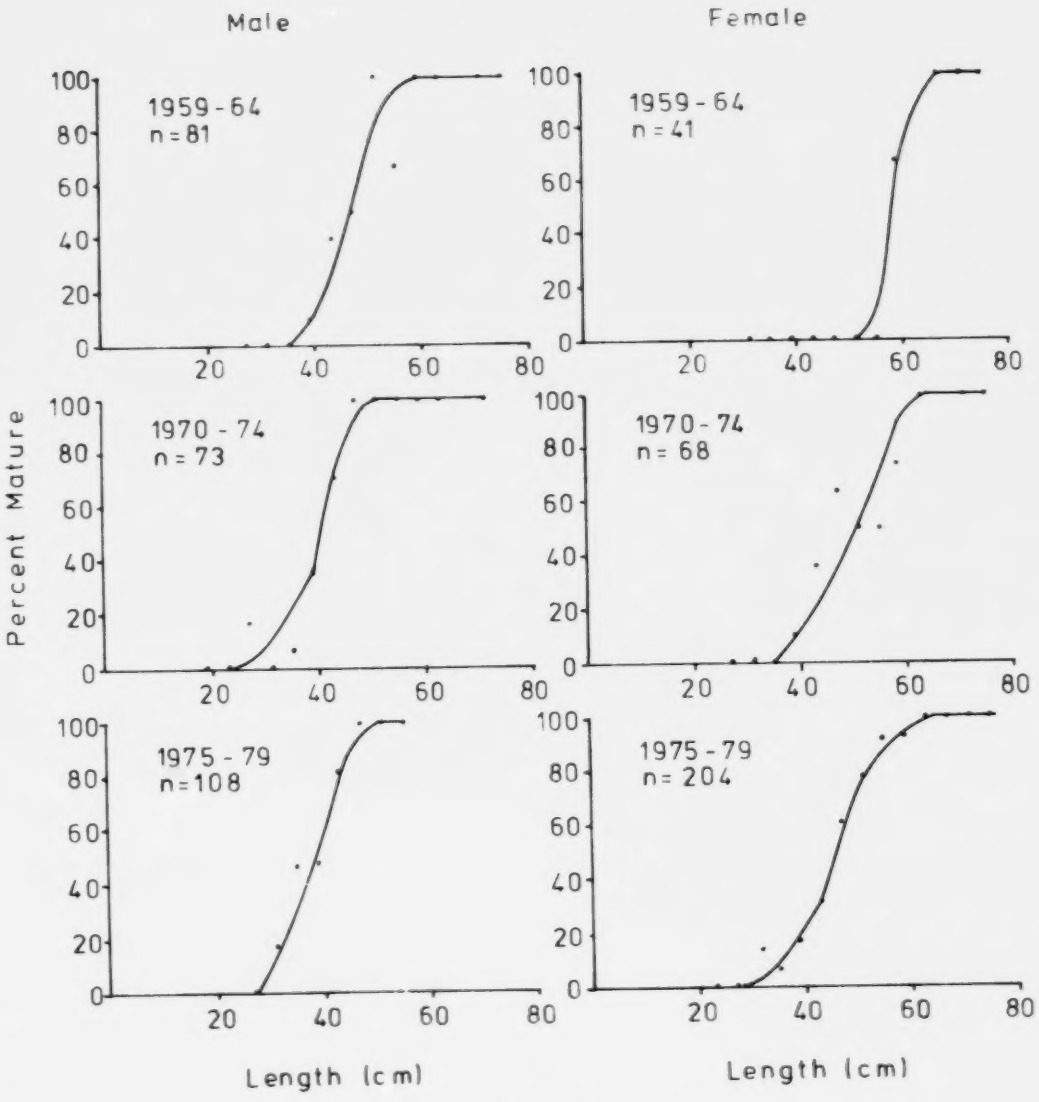

Fig. 3. Maturity ogives for white hake sampled during Canadian groundfish surveys in Subdiv. 4Vn, 1959-1979.

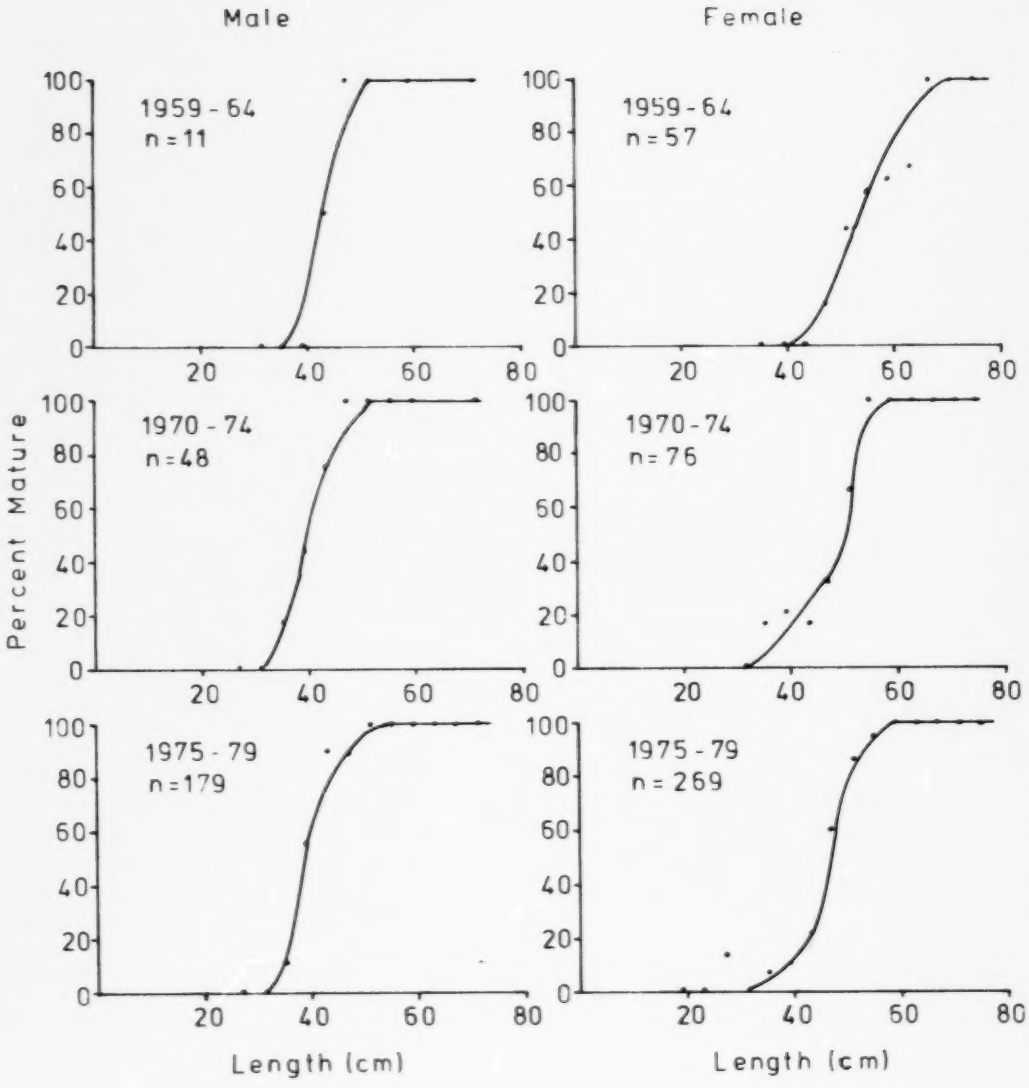

Fig. 4. Maturity ogives for white hake sampled during Canadian groundfish surveys in Subdiv. 4Vs, 1959-1979.

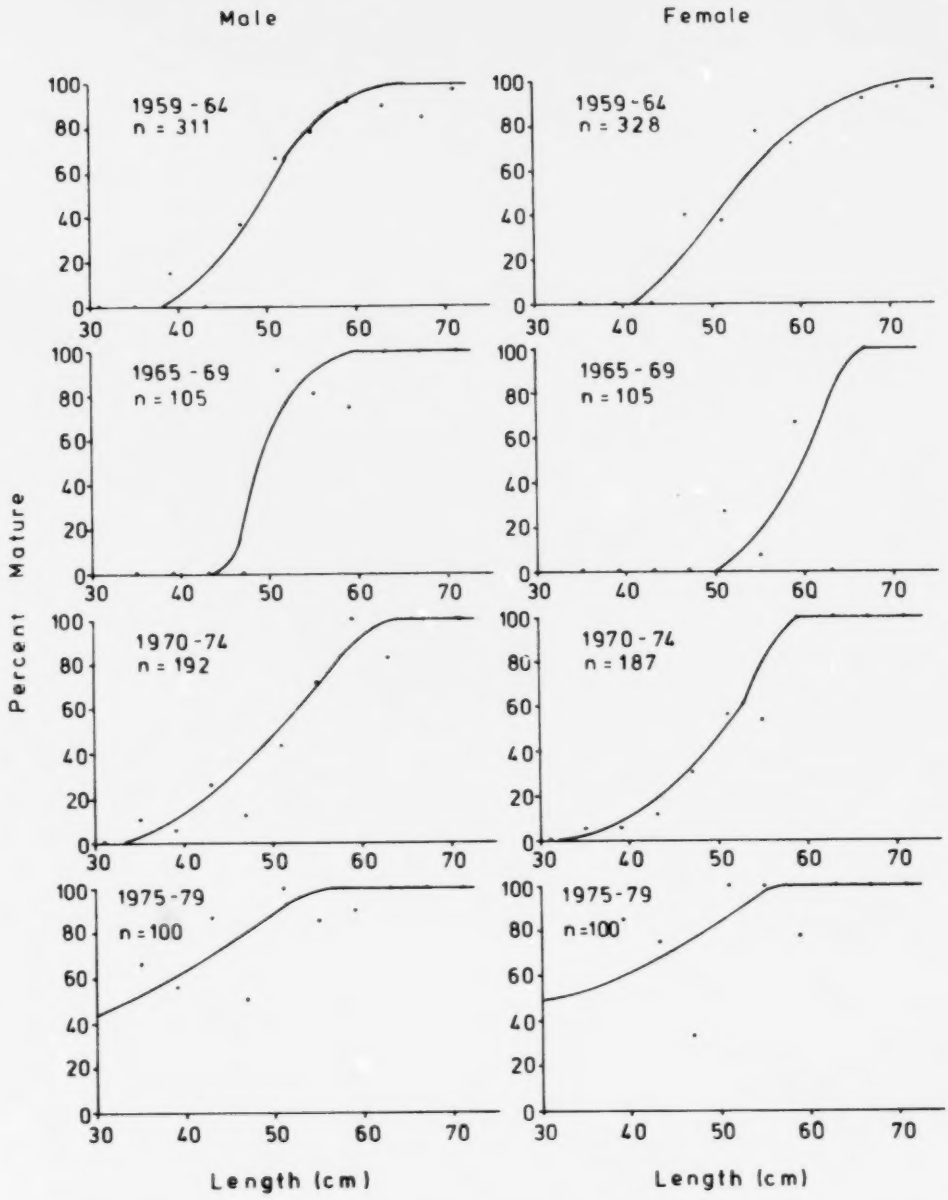

Fig. 5. Maturity ogives for pollock sampled during Canadian groundfish surveys in Div. 4W, 1959-1979.

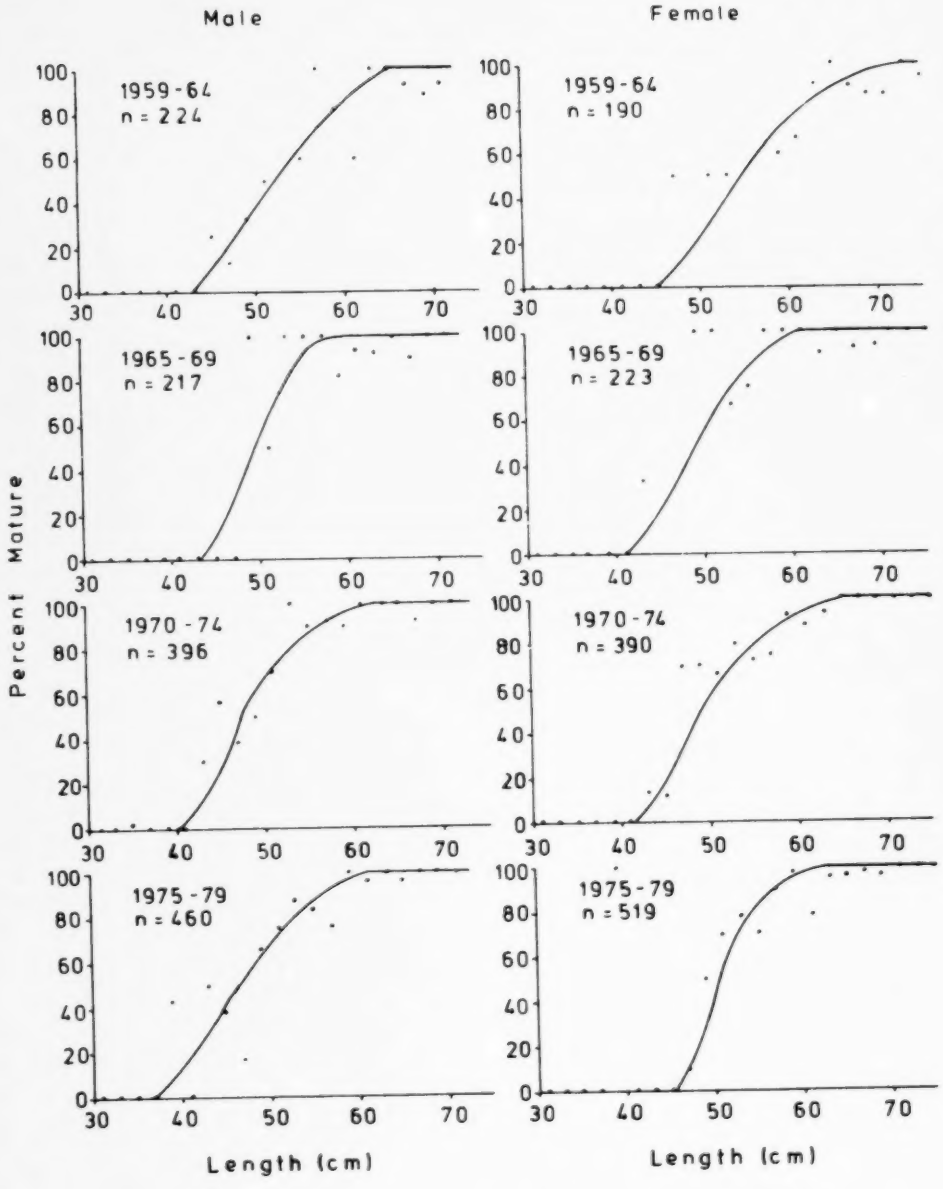

Fig. 6. Maturity ogives for pollock sampled during Canadian groundfish surveys in Div. 4X, 1959-1979.

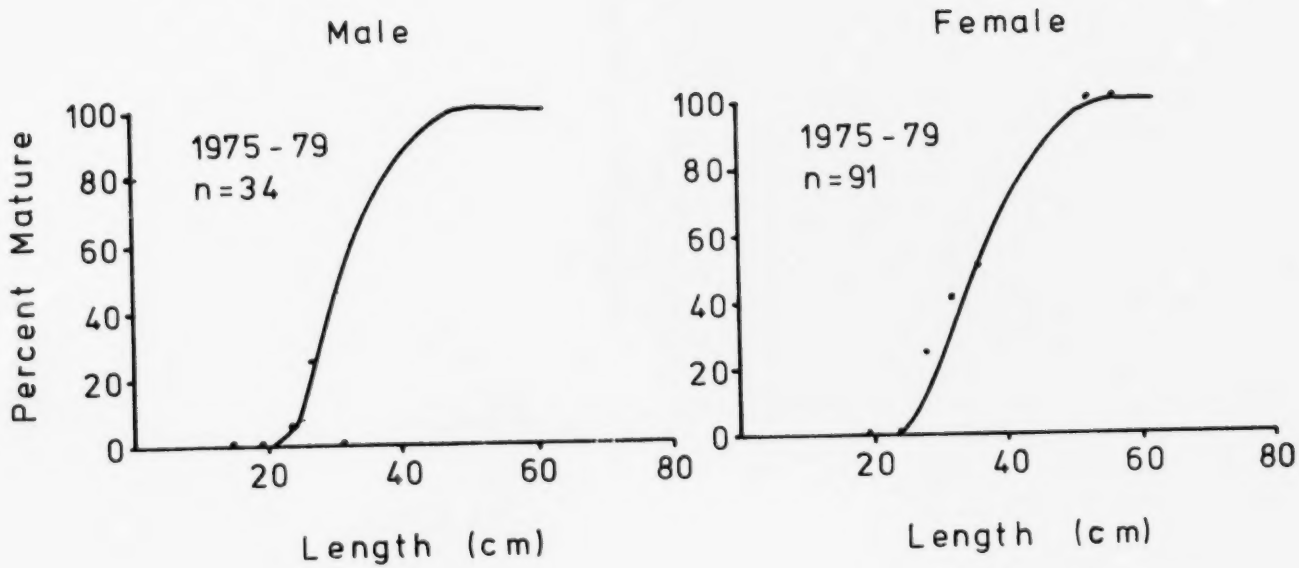

Fig. 7. Maturity ogives for longfin hake sampled during Canadian groundfish surveys in Subdiv. 4Vn, 1975-1979.

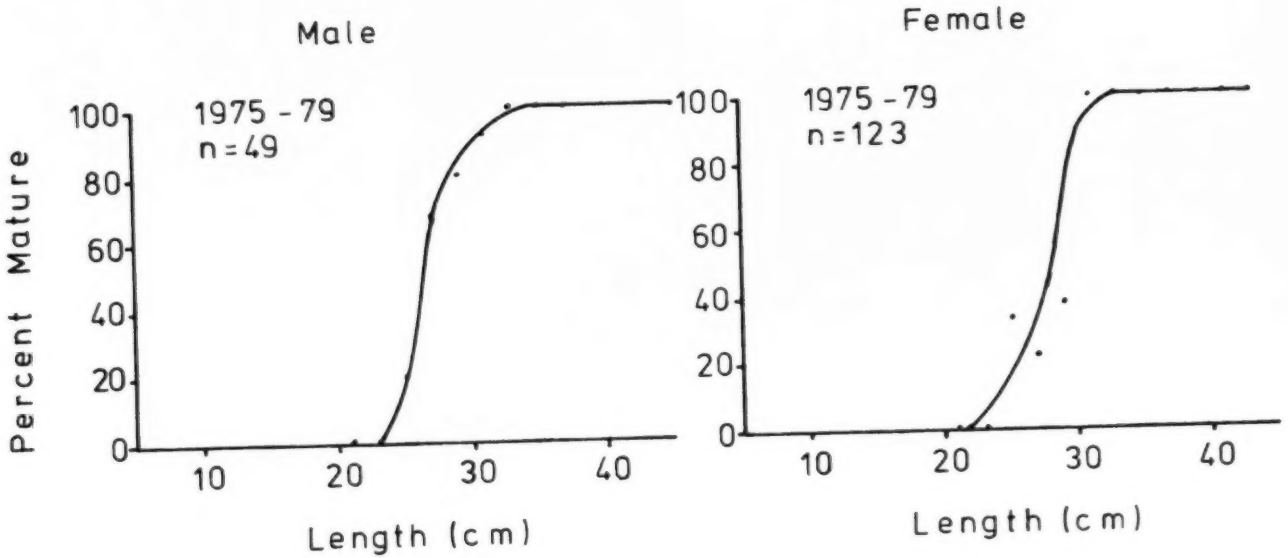

Fig. 8. Maturity ogives for silver hake caught during Canadian groundfish surveys in Subdiv. 4Vs, 1975-1979.

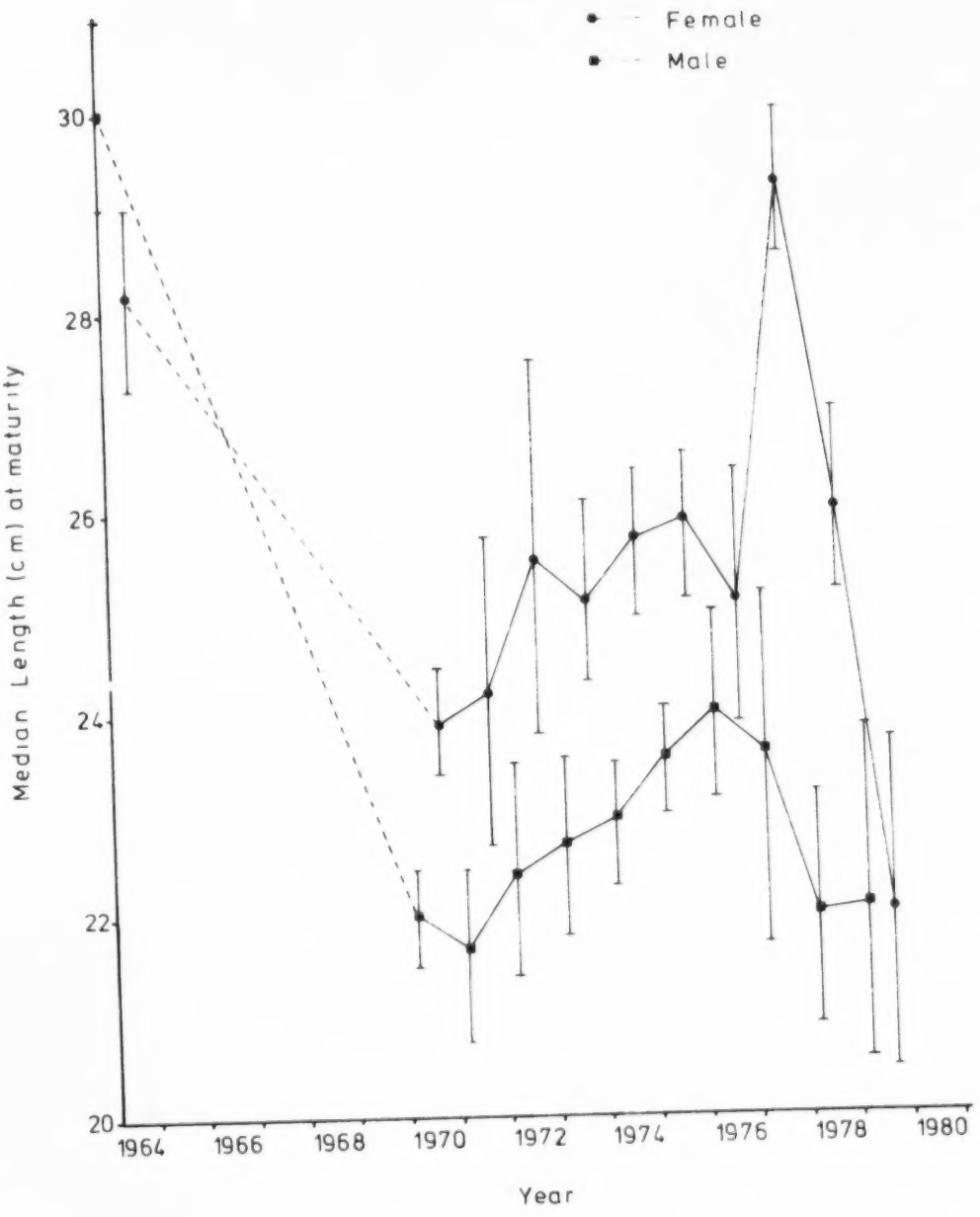

Fig. 9. Median length at sexual maturity for silver hake caught during July Canadian groundfish surveys in Div. 4W, 1964-1979. Vertical bars indicate 95% confidence limits.

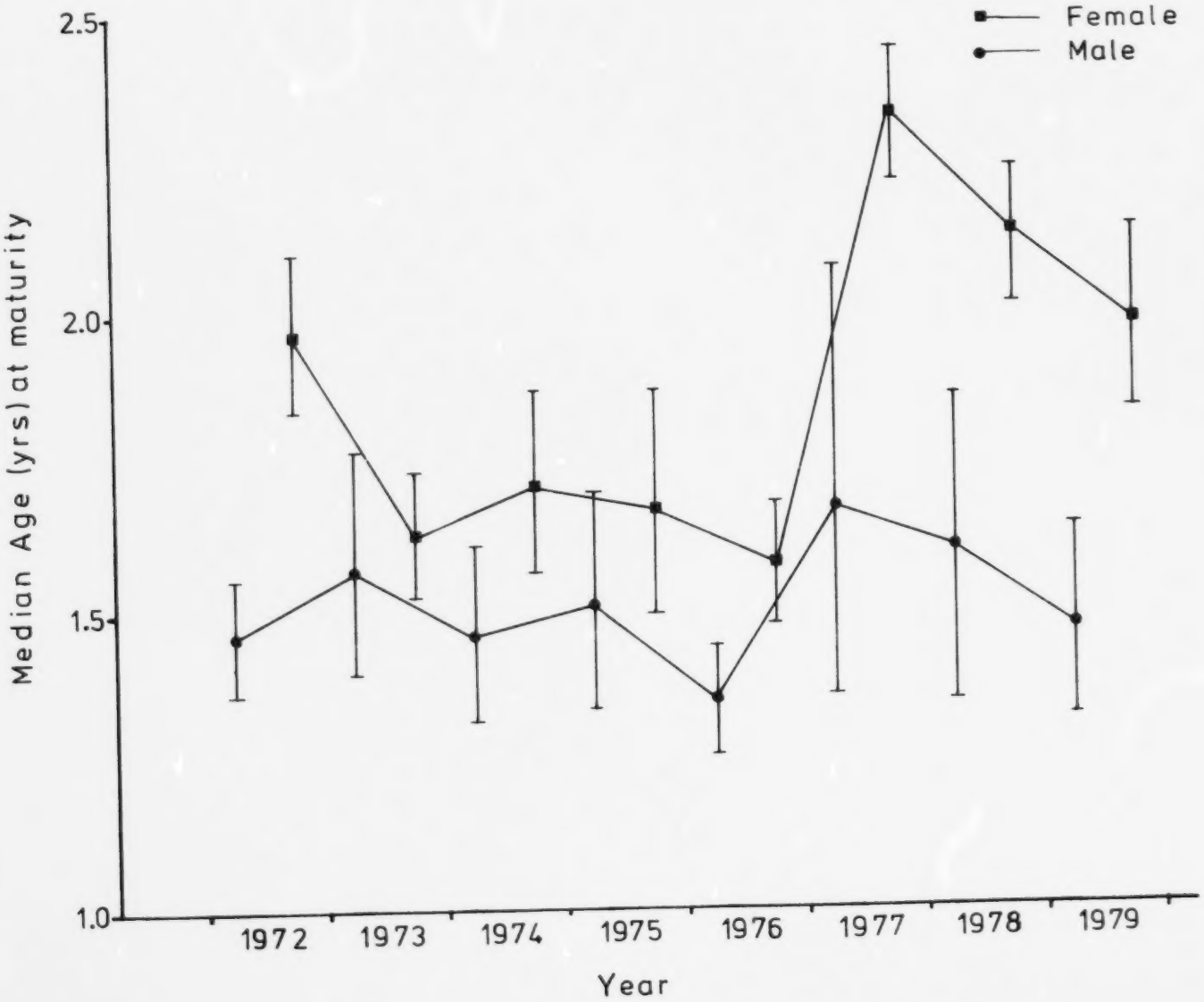

Fig. 10. Median age at sexual maturity for silver hake caught during July Canadian groundfish surveys in Div. 4W, 1972-1979. Vertical bars indicate 95% confidence limits.

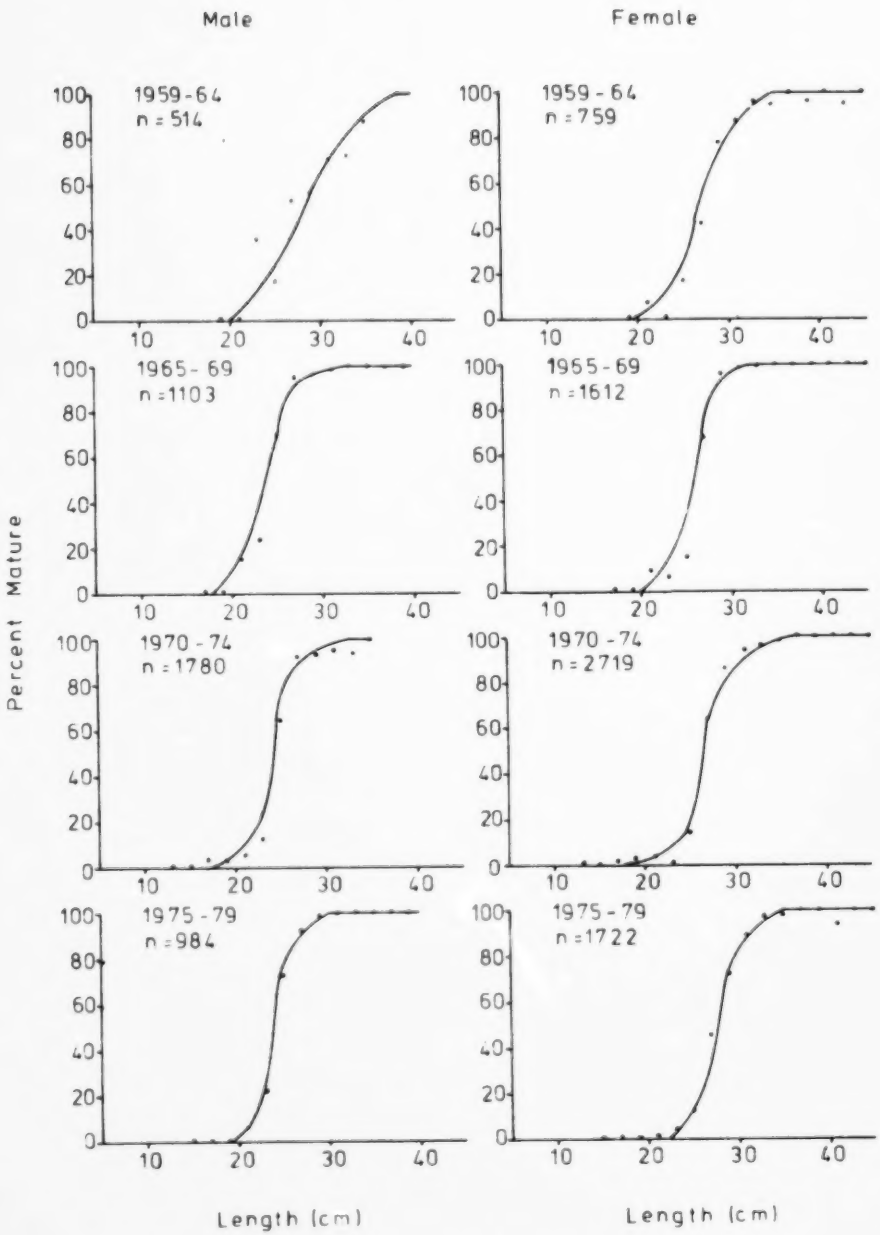

Fig. 11. Maturity ogives for silver hake caught during Canadian groundfish surveys in Div. 4W, 1959-1979.

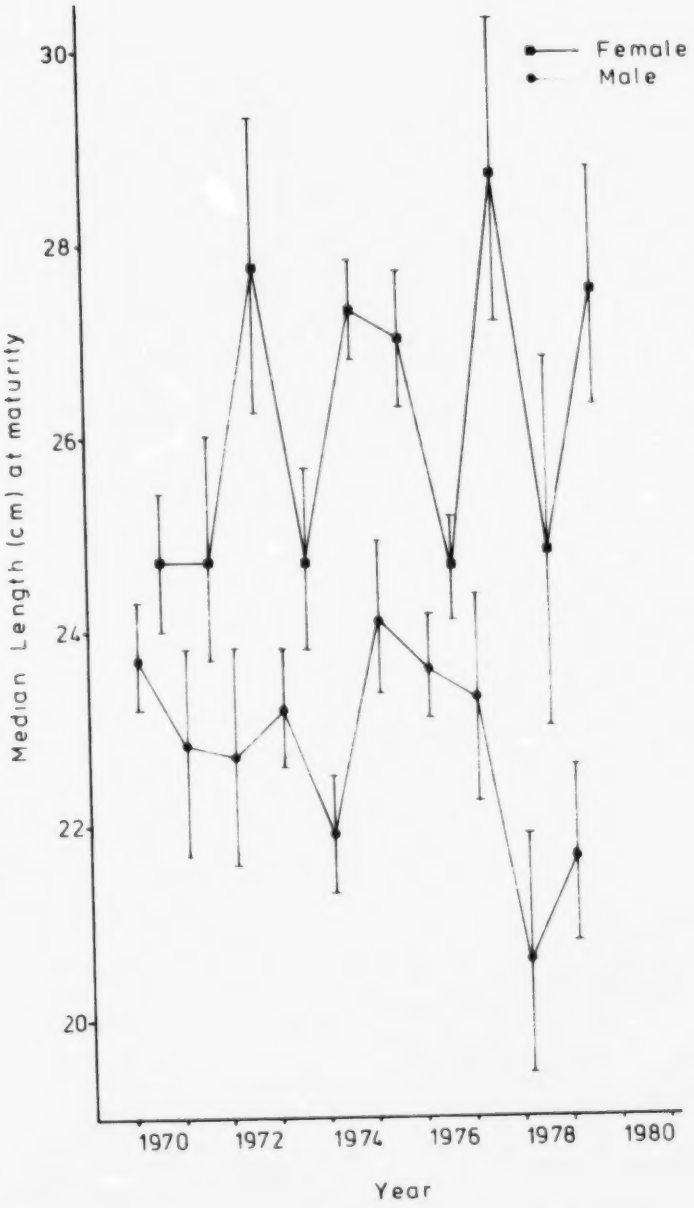

Fig. 12. Median length at sexual maturity for silver hake caught during July Canadian groundfish surveys in Div. 4X, 1970-1979. Vertical bars indicate 95% confidence limits.

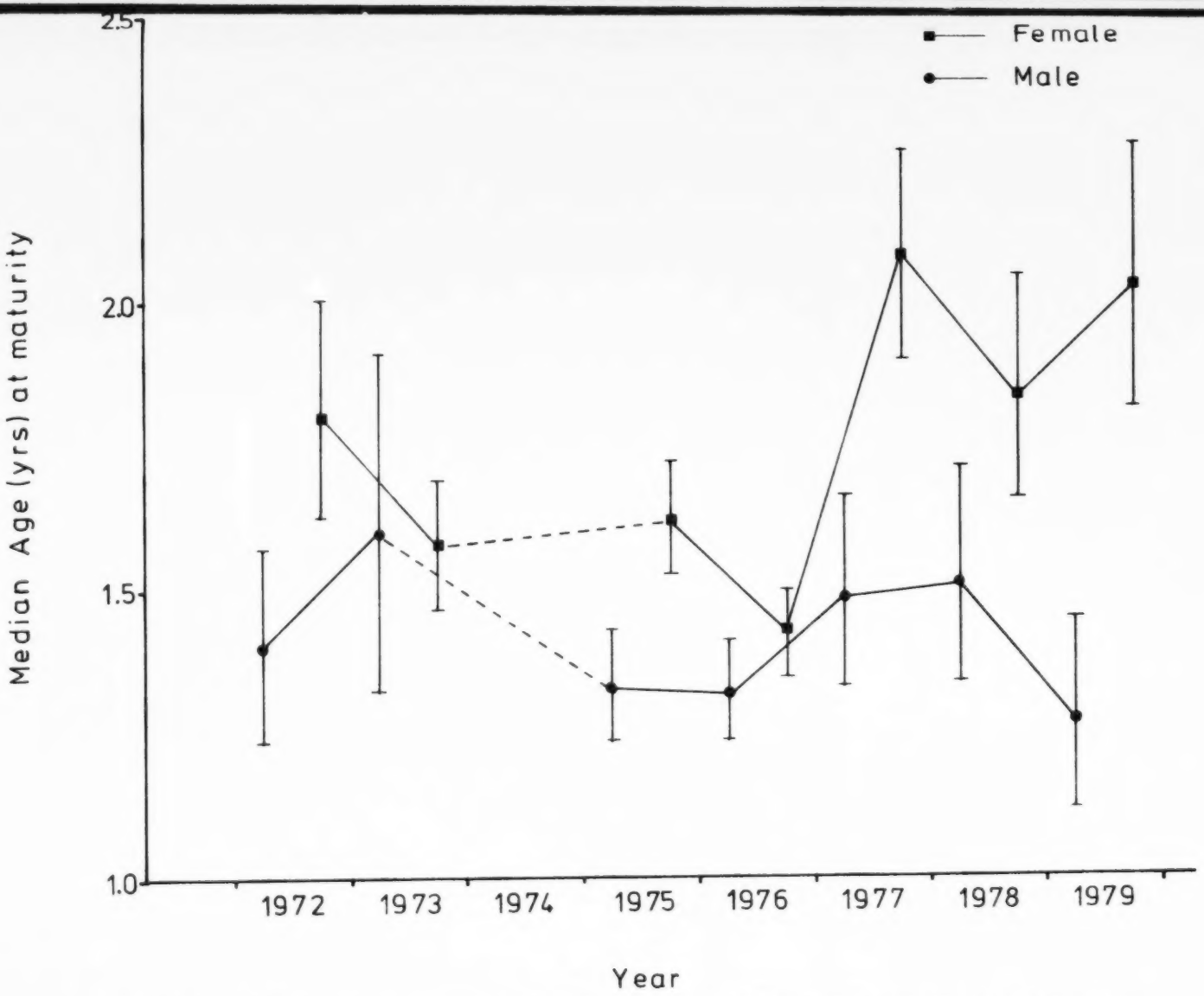

Fig. 13. Median age at sexual maturity for silver hake caught during July Canadian groundfish surveys in Div. 4X, 1972-1979. Vertical bars indicate 95% confidence limits.

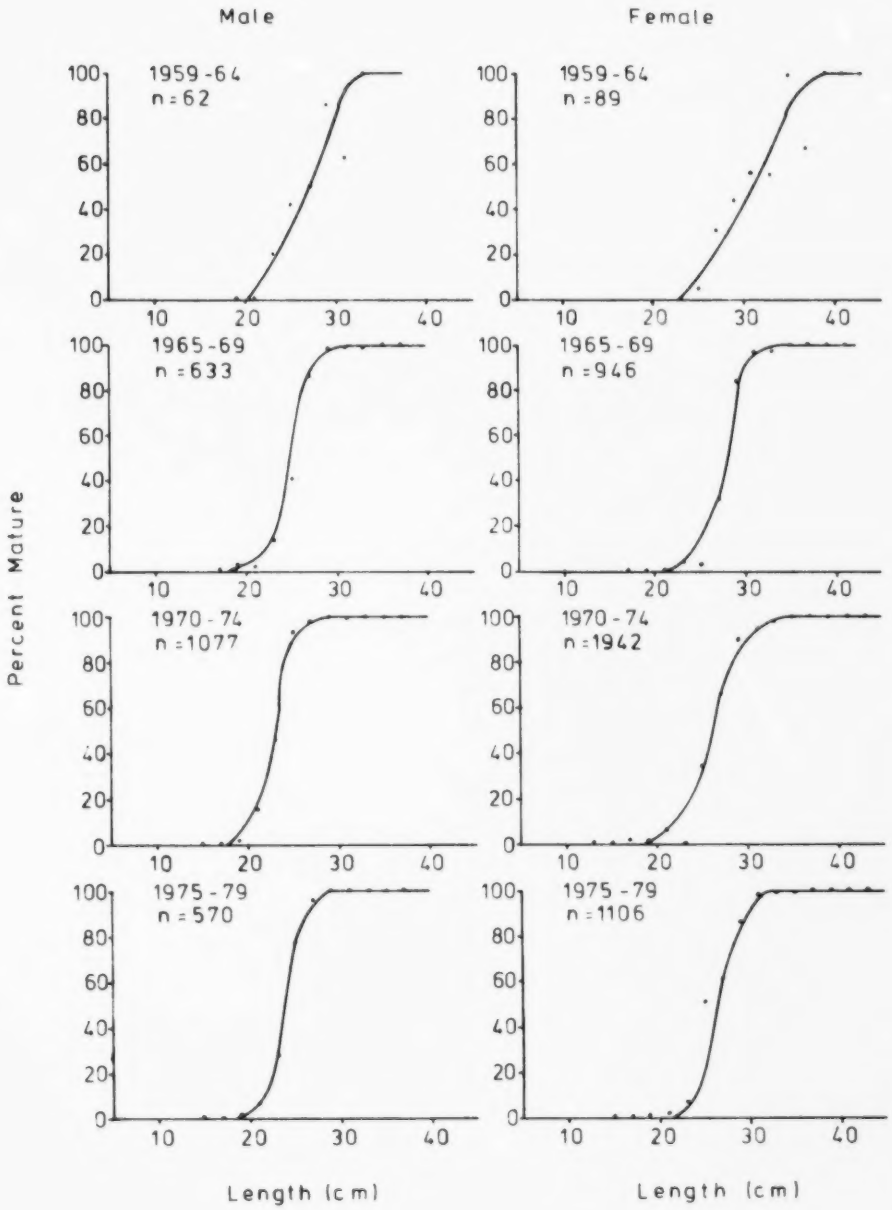

Fig. 14. Maturity ogives for silver hake caught during Canadian groundfish surveys in Div. 4X, 1959-1979.